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THE UNITED STATES OF AMERICA

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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

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[X] *Additional inventors are being named on the* 1 *separately numbered sheets attached hereto.*

TITLE OF THE INVENTION (280 characters max)

RECOGNITION OF BANKNOTE DENOMINATION IN AUTOMATIC MONEY PROCESSING DEVICES

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

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ENCLOSED APPLICATION PARTS (ch

[X] Specification *Number of Pages* 3

[ ] Drawing(s) *Number of sheets*

[ ] Application Data Sheet. See 37 CFR 1.76

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISION

[X] Applicant claims small entity status. See 37 CFR 1.27

[X] A check or money order is enclosed to cover the filing fees

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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

[X] No.

[ ] Yes, the name of the U.S. Government agency and the Government contract number are: ____________

Respectfully submitted,

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Date July 10, 2002

REGISTRATION NO. *(if appropriate)* 24,156

Docket Number: 205,806

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

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PROVISIONAL APPLICATION COVER SHEET
Additional Page

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Docket Number	205,806	Type a plus sign (+) inside this box →	+

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Recognition of banknotes denomination in automatic money processing devices

Field of the invention
The invention relates to the field of currency banknote identification, denomination, and counting.

Background of the invention
Banknote identification and denomination features are major advantages of any currency counting machine. There are many existing approaches that use various techniques (see for example the methods disclosed in US patent 5680472 by CR Machines, and US patent 5467405 by Cummins-Allison). Most of there techniques are based on well known methods of pattern recognition founded and developed in image processing (for example, see the "Handbook of Pattern Recognition and Image Processing", ed. T. Young, Academic Press, 1986).
Another common feature of the existing denomination algorithms is the usage of "predefined strips" selected on a banknote image. The strips may be extracted from different places of the banknote: edges, some areas from central part, visible in reflected and transmitted light, etc. While such methods allow rather robust identification and denomination, they require serious research of the banknotes properties and should take into account subtle differences among the banknotes from different Issues of the same denomination, may fail with corrupted (but still acceptable) banknote, etc. Typically, denomination algorithms of this kind use reflectance data in high resolution form (grayscale and sometimes color images of banknotes of quite high spatial resolution). This leads to relatively complex embedded software with high requirements to memory (both RAM and EPROM) and processing power of the currency counting machine.

Summary of the invention
Proposed method of arbitrary currency identification and denomination is also based on known image processing techniques, while has no one of the flaws discussed above. It can be adapted to images of low brightness and spatial resolutions, and does not require either prior knowledge of banknote structure, or extensive research activity to identify a new currency/denomination.
The whole approach comprises two stages - learning and operational. During learning stage, which may be performed on any workstation, a number of banknote discriminators are collected using a representative set of banknotes of every denomination. Then, on the operational stage, which is specially designed to be embedded, scanned image of yet unknown banknote is correlated (compared) with a set of discriminators. The results of comparisons are fed to a rule-based decision making section that generates either known identification code, or signals unknown banknote. The identification code can include information about currency (e.g., USD, Euro, CAN), denomination (5 units bill, 100 bill), and orientation (front side up, upside down, etc).
The set of discriminators may have of the information about banknote size, as well as a number of tables of the banknote image size that contain (for every pixel, or group of pixels) the values of probability of certain brightness of those pixels. These probabilities are obtained by scanning a subset of banknotes with following statistical processing. Then, on the operational stage, the algorithm simply verifies if the scanned image of entire banknote has meaningful probability to be one of the known currency and denomination.

Detailed description of the invention
The preferred embodiment of the method realizes the algorithm for the black and white (binary) images of the banknotes in low spatial resolution (down to 10 dpi). With this approach discrimination tables are reduced to binary masks and discrimination process is simplified to some logical operations and simple (and fast) arithmetical calculations. The text below describes identification process for US dollars bills for simplicity. Other currencies are processed using the same approach enforced with information about size of the scanned banknote.

The learning stage of the method produces two binary masks for every denomination, one mask for "mostly black" pixels, and another one for "mostly white" pixels. "Mostly black" or "mostly white" are the pixels which found to be black or white respectively, on 90% of the used set of banknotes. White and black pixels in the context of binary images are the pixels with brightness 1 (one) and 0 (zero). The masks are not complementary, and there may be some pixels that do not appear in either mask. These masks are then transferred to and stored in the counter.
The scanning facility of the banknote counter scans banknote and produces binary image which are input to operational stage of the algorithm. At the beginning of the denomination process the image is duplicated, and one instance is inverted. Then original image is masked using the stored binary mask of "mostly white" pixels, while inverted image is masked with the binary mask of "mostly black" pixels. The result of such operation comprises two images – the first one contains the pixels which are white on the original image as well as on the "mostly white" mask image, and the other one contains the pixels that are black on the original image but white on the "mostly black" mask image. Numbers of white pixels on both resulting images are then compared with numbers of white pixels on the corresponding masks. Result of the comparison is the ratios of the numbers – one ratio for "mostly white", and another one for "mostly black". These ratios may be interpreted as a measure of equality (distance) between the scanned banknote image and "prevailing image" of a denomination. The closer ratio to 1.0, the more likely that the banknote is of such (as of the used masks) denomination. This routine is performed using all available masks. The calculated ratios are input to decision making function. The decision making function is rule based and may be implemented using variety of techniques. The preferred embodiment of the method implements the simplest algorithm which uses thresholds that are set during learning stage as well. Thus, final stage of decision making can be described using natural language as:

If the highest ratio is high enough, and its difference from the next (less) ratio is big enough (more than the threshold), then the banknote has certain denomination.
Otherwise, it is classified as an unknown document.

In another preferred embodiment the scanned image is correlated with the stored masks and a correlation coefficient is calculated. Then the rule-based decision making function that has been described above is invoked.

Claims
What is claimed is:
1. A method for arbitrary currency banknote identification and denomination, the method comprising the steps of:
   banknote scanning using any means for document scanning
   comparison of the scanned image with a number of predefined discriminators
   mapping the results of the comparison into number of predefined identity codes
   displaying the codes using any means for information displaying
2. The method according the claim 1, wherein entire banknote is scanned.
3. The method according the claim 1, wherein a number of arbitrary sub-areas of the banknote are scanned.
4. The method according the claim 1, wherein the scanning is performed using transmitted light of any wavelength.
5. The method according the claim 1, wherein banknote scanning is performed using transmitted infrared light.
6. The method according the claim 1, wherein the scanned banknote image has more than 1 bit per pixel brightness resolution.
7. The method according the claim 1, wherein the scanned banknote image has 1 bit per pixel brightness resolution.
8. The method according the claim 6, wherein the predefined discriminators are tables of the size equal to the size of the scanned image and comprises the numbers representing probability of a pixel brightness to be less than a threshold value (low threshold) or more than another threshold value (high threshold) on a banknote of certain currency and/or denomination.
9. The method according the claim 8, wherein the said thresholds are equal.

10. The method according the claim 7, wherein the predefined discriminators are tables of the size equal to the size of the scanned image and comprises the numbers representing probability of a pixel to be zero or one (black or white) on a banknote of certain currency and/or denomination.
11. The method according the claim 7, wherein the predefined discriminators are 1-bit per pixel masks of the size equal to the size of the scanned image.
12. The method according the claim 11, wherein one in a mask means that the said probability is higher than a threshold value (high threshold) and zero in a mask means that the said probability is lower than a threshold value (low threshold).
13. The method according the claim 12, wherein the said thresholds are equal
14. The method according the claim 1, wherein the comparison comprises the statistical methods.
15. The method according the claim 7, wherein the comparison comprises the statistical methods.
16. The method according the claim 11, wherein the comparison comprises the calculation of the scanned image and discriminator area ratio.
17. The method according the claim 1, wherein the number of discriminators are equal to two or four per currency.
18. The method according the claim 11, wherein the number of discriminators are equal to two or four per currency.
19. The method according the claim 1, wherein the predefined identity codes contain special code for unidentifiable documents.
20. The method according the claim 1, wherein the mapping comprises lookup table.
21. The method according the claim 1, wherein the said displaying means comprise remote access.